Cooling Tower Water Quality Parameters for Degraded Water

Contract #: 100-98-001
Contractor: Michael N. DiFilippo, Consultant
Contract Amount: $140,000
Contractor Project Manager: Michael N. DiFilippo
Commission Project Manager: Joe O'Hagan
Commission Contract Manager: Joe O'Hagan

The Issue

Thermal power plants are the largest industrial water users in California. It takes eight to nine gallons of water to produce one kilowatt of electricity,[1] and California's in-state fossil power plants generated 170,682 gigawatthours (GWh) of electricity in 2001.[2] Consequently, 1.4 to 1.5 trillion gallons of water were required to generate that power.

Thermal (steam-driven) power plants are the largest industrial consumers of water in California. Most of the water is used for cooling.

Given the increasing demands on California's limited freshwater supplies,[3] the state encourages power plants and other industries to use *degraded water* supplies whenever possible.[4] Degraded water sources are those that are not readily suitable for most other uses, because they contain naturally occurring or human-induced pollution. Such water sources include wastewater from treatment plants, naturally occurring brackish groundwater, and surface and groundwater bodies contaminated by pesticides, solvents, and other pollutants. Use of degraded water frees a corresponding amount of freshwater for more appropriate applications, such as human consumption, aquatic habitat viability, and agricultural irrigation.

[1] Firsching, Frank. 2002. "Water and the power industry." [http://utilitybusiness.com/ar/power_water_power_industry/index.htm].

[2] Includes coal, oil, natural gas, and biomass facilities. [www.energy.ca.gov/electricity/gross_system_power.html].

[3] Given projected increases in the state's population, the California Department of Water Resources forecasts a water shortfall of 2.4 million acre-feet in an average-rainfall year. See California Department of Water Resources, 1998, *The California Water Plan Update Bulletin* 160-98 [http://rubicon.water.ca.gov/pdfs/es/esch1.pdf].

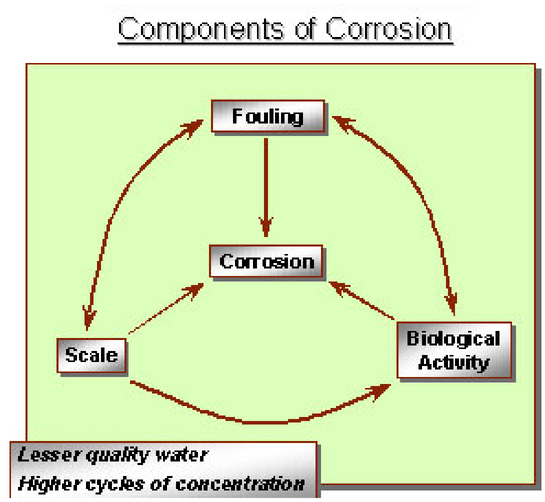
[4] California Water Code. Sections 13510–13512, 13550–13556, 13575–13583 (Water Recycling Act of 1991).

Thermal power plants use the vast majority of their water—up to 95%—for cooling.[5] Power plant cooling systems circulate water to lower the temperature of the steam that generates power, so that it reverts to water once again and can be reused. The now-warm cooling water is pumped to the cooling towers, which dissipate the heat to the atmosphere by dripping or spraying the water over fill materials in the tower and blowing air on it. The water that has not evaporated then can either be recycled through the cooling system or discharged.

The majority of California's power plants use closed-loop cooling systems—a much more efficient process than "once-through" cooling systems, which do not recirculate cooling water. Use of degraded water would enable even greater conservation of freshwater supplies.

However, degraded water can cause problems in closed-loop systems, for two reasons: (1) compared to freshwater, it contains higher concentrations of mineral salts and other components, which can increase scaling, corrosion, and biofouling in the cooling equipment, and (2) recycling the water through the cooling towers causes these impurities to become more concentrated, further increasing adverse effects and potentially creating environmental problems when the water is ultimately discharged. Cooling tower discharge water can adversely affect the environment by releasing higher concentrations of substances such as ammonia, phosphates, and toxic organic compounds into an aquatic environment.

Although some types of degraded water supplies have been used for power plant cooling, the adverse effects can carry a high price tag, both in terms of electricity production and availability. For example, increased scale deposits of just 1/8 inch can reduce the efficiency of a power plant heat exchanger by 40%—greatly reducing the amount of electricity that can be generated from the same amount of fuel.[6] In addition, plant equipment damage and efficiency reductions caused by increased corrosion or fouling increases energy companies' operation and maintenance costs (which are ultimately passed on to consumers) and can cause plants to shut down more often for repairs, hampering the reliability of the state's electricity system. Cooling water quality is also a concern for power plant operators because it can affect occupational health (e.g., cooling towers harbor Legionella bacteria).



All power plant cooling systems battle corrosion. Compared to freshwater, degraded water typically contains even higher levels of the minerals and organic matter that cause scale and biofouling, ultimately leading to corrosion.

Considering these factors, it is necessary to develop and implement new sets of water quality parameters that can satisfactorily account for the changing quality of water, technological transformation, and stringent regulations. Water quality parameters are sets of information on the physical properties of the water (such as temperature, pH, and mineral content). Together, these parameters can be evaluated to determine whether water from a particular source

[5] Maulbetsch, John S. 2002. *Comparison of Alternate Cooling Technologies for California Power Plants.* EPRI and California Energy Commission. 500-02-079F.

[6] Myron L Co. website [www.myronl.com/applications/boilerapp.htm].

is appropriate for certain uses. Power plant cooling system operators use water quality parameters to determine, for example, what kind of water treatment may be necessary to keep the cooling water from scaling or corroding equipment, or when water is safe to be discharged back into the natural environment. These parameters help power plants generate electricity reliably and efficiently, while ensuring worker and environmental health.

However, the current cooling water quality criteria are often overly conservative and simplistic, and do not specifically address the use of degraded water supplies. Updated water quality criteria will boost the effective, safe use of degraded water.

Project Description

This project developed a methodology to evaluate source waters that could be used for power plant cooling systems. At present, generalized indices and water quality criteria are typically used to screen and evaluate potential water sources for cooling. Often these criteria are overly conservative, and consequently, many candidate water sources are considered unusable. This project developed step-by-step procedures to analyze source water chemistry on a more realistic basis.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound electricity.** The more sophisticated analytical procedures developed in this project will enable greater use of degraded water supplies—and thus help conserve California's limited freshwater supplies for more appropriate uses. Freshwater savings at a single 500–1000 MW combustion turbine/combined-cycle plant (with closed-loop cooling) would range about 3.5 to 5 million gallons per day.[7]

- **Providing reliable electricity.** Higher incidences of corrosion or biofouling in cooling systems can cause more frequent maintenance outages. The tools developed by this project equip power plant operators to determine appropriate water quality parameters, thereby enabling them to reduce downtime and increase electricity production.

- **Providing affordable electricity.** As competition for limited freshwater grows more intense, use of degraded water will represent increasing cost savings to power producers—savings that can be passed along to consumers. This research promotes further cost containment by equipping power producers to avoid the potential adverse effects (i.e., maintenance outages and efficiency losses) associated with inappropriate degraded water sources.

Results

This project developed a water quality calculator that can be used to conduct site-specific evaluations of degraded source waters being considered for power plant cooling water. The

[7] California Energy Commission. July 2001. *Environmental Performance Report of California's Electric Generation Facilities.* 700-01-001. p. 28.

calculator is provided in the final report as a downloadable Excel spreadsheet. The report also offers detailed guidance on the following topics:

- The evolution of simple calcium carbonate indices and generalized concentration guidelines currently used as water quality criteria for cooling towers
- Ion chemistry, including how complex interactions can increase the solubility of sparingly soluble salts in water
- Commercial software to predict ion behavior
- Specialty chemicals for (1) scale control with threshold scale inhibitors and dispersants and (2) corrosion inhibition for mild steel and copper alloys
- How to prepare source water chemistry data for analysis
- Site-specific water quality criteria for cooling towers—a step-by-step analytical procedure

Source water pretreatment, cooling system materials of construction, and zero-liquid discharge strategies were not covered in this research.

The more sophisticated analytical procedures developed by this project demonstrated that many water sources deemed unusable by the standard, overly conservative criteria are actually usable when evaluated in a more thorough, site-specific manner.

Final Report

The final report on the results of this work, *Cooling Tower Water Quality Parameters for Degraded Water*, is posted on the Energy Commission website at:
www.energy.ca.gov/2005publications/CEC-500-2005-170/CEC-500-2005-170.PDF.

Contact

Joe O'Hagan • 916-653-1651 • johagan@energy.state.ca.us